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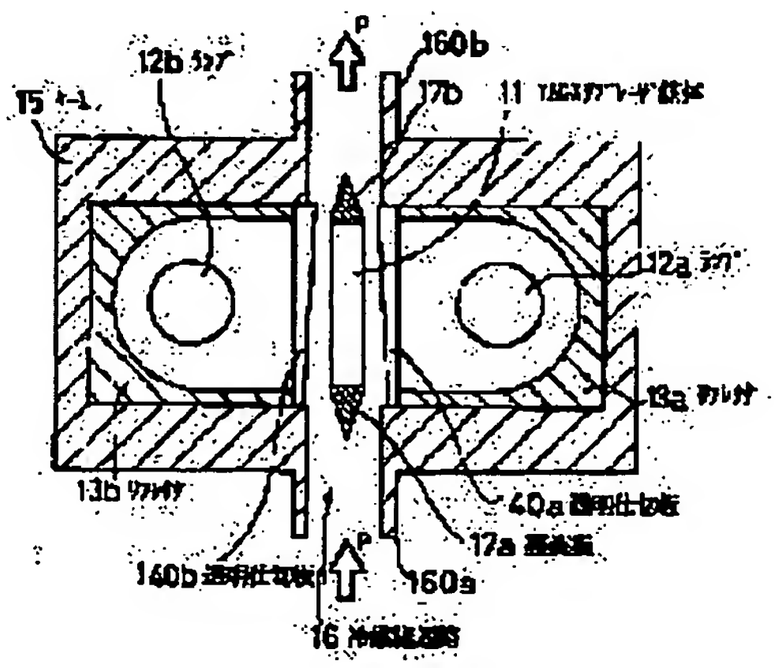
(54) SOLID LASER DEVICE

(57)Abstract:
PURPOSE: To obtain a solid laser device which does not generate any temperature distribution in a solid laser medium even if a temperature difference is produced in a refrigerant by reducing the channel sectional area of a region cooling the solid laser medium at a downstream side as compared with that at an upstream side.
CONSTITUTION: A surface of transparent screening plates 140a and 140b opposing lamps 12a and 12b is nearly in parallel with the surface of a YAG slab laser medium 11 and that opposing the surface of a medium 11 is inclined so that the thickness is increased from an upstream side toward a downstream side. Then, the channel sectional area of a region cooling the medium 11 of a refrigerant circulation path 16 is reduced at the downstream side and a cooling water is delivered from a refrigerant delivery port 160b through a channel which is formed by the rear and front surfaces of the medium 11 and the transparent screening plates 140a and 140b. Therefore, when the ratio of sectional area between the upstream and downstream sides is set properly, the amount of cooling can be made equal at the upstream and downstream sides, thus cooling the solid laser medium without generating a non-uniform temperature distribution.



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* NOTICES *

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2.**** shows the word which can not be translated.
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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to solid-state-laser equipments which used the solid-state-laser medium, such as a laser oscillation machine and an optical amplifier.
[0002]
[Description of the Prior Art] As conventional solid-state-laser equipment, what was indicated by JP,2-201980,A is known, for example. Drawing 10 is the fragmentary sectional view showing the outline configuration of the principal part of this conventional solid-state-laser equipment slack YAG slab laser equipment.
[0003] In drawing 10 , a sign 11 is the YAG slab laser medium which made long tabular one. Drawing 10 is the fragmentary sectional view cut in the field which intersects perpendicularly with the longitudinal direction of this YAG slab laser medium 11. In the part which counters the field of the front flesh side of this YAG slab laser medium 11, the excitation light source slack lamps 12a and 12b are arranged, respectively, and Reflectors 13a and 13b are formed in the perimeter of these lamps 12a and 12b, respectively. Moreover, between Lamps 12a and 12b and the field of the front flesh side of the YAG slab laser medium 11, the glass transparence dashboards 14a and 14b intervene, respectively. And while the these YAG(s) slab laser medium 11, Lamps 12a and 12b, Reflectors 13a and 13b, and the transparence dashboards 14a and 14b are contained by the case 105, the refrigerant circulation way 16 which circulates the refrigerant slack cooling water which cools the YAG slab laser medium 11 is formed between the field of the front flesh side of the YAG slab laser medium 11, and the transparence dashboards 14a and 14b. This refrigerant circulation way 16 circulates cooling water toward the other-end section also in the cross direction of the YAG slab laser medium 11 from an edge, as shown by the arrow head p of drawing 10 . In addition, the straightening vanes 17a and 17b which served as the heat insulation member are attached in the both-sides section in the cross direction of the YAG slab laser medium 11. Moreover, although water cooling also of the lamps 12a and 12b is carried out in fact, the configuration of the point etc. is omitted in drawing 10 .
[0004] Moreover, as a solid-state-laser medium, in the solid-state-laser equipment using the crystal and laser glass of YAG etc. of the shape of the shape of a rod other than an above-mentioned slab laser medium, or tubing, refrigerants, such as liquids, such as cooling water, air, and gas, are usually poured along the direction of an optical axis, and the laser medium is cooled.
[0005]
[Problem(s) to be Solved by the Invention] By the way, in above-mentioned conventional YAG slab laser equipment, the cooling water in the downstream of the refrigerant circulation way 16 is cooling water which cooled the YAG slab laser medium 11 and already got warm by the upstream. For this reason, the cooling degree of the downstream became small inevitably as compared with the upstream, consequently the problem that the temperature distribution of the cross direction by the difference of this cooling degree arose was in the YAG slab laser medium 11. Although relaxation is carried out because such temperature distribution raise the rate of flow of cooling water, since there is a limit in the injection

pressure of a pump which circulates cooling water and there is a limit also in proof-pressure capacity, such as piping and a lamp house, it is a problem unsolvable only by raising the rate of flow of cooling water. Thus, when uneven temperature distribution occur crosswise [of slab], the direction of outgoing radiation of a laser beam will change with excitation inputs, the transverse mode will become unstable, or oscillation effectiveness will fall. For this reason, when this YAG slab laser equipment was used for the high power laser oscillation equipment used for cutting processing of a metal, welding processing, punching processing, etc., a processing location, processing width of face, the processing depth, etc. changed, and un-arranging [that highly precise processing became difficult] had arisen. Moreover, also when this YAG slab laser equipment was used for example, as the trimming of the electrical part which needs high stability for the direction of outgoing radiation and the transverse mode of a laser beam, or laser equipment for wavelength conversion, there was a problem that sufficient stability was not acquired.

[0006] Such a situation was the same as a solid-state-laser medium also in the solid-state-laser equipment which used the crystal and laser glass of YAG etc. of the shape of the shape of a rod other than a slab laser medium, or tubing.

[0007] This invention is made under an above-mentioned background, and even if a temperature gradient arises in the refrigerant in the upstream and the downstream of a refrigerant circulation way which circulate the refrigerant which cools a solid-state-laser medium, it aims at offering the solid-state-laser equipment it was made for temperature distribution not to produce to a solid-state-laser medium.

[0008]

[Means for Solving the Problem] The solid-state-laser equipment (1) which cuts in this invention in order to solve an above-mentioned technical problem, In the solid-state-laser equipment which has a solid-state-laser medium, the excitation light source which excites this solid-state-laser medium, and the refrigerant circulation way which circulates the refrigerant which cools said solid-state-laser medium, it considered as the configuration characterized by to make the downstream small for the passage cross section of the field which cools said solid-state-laser medium in said refrigerant circulation way as compared with the upstream.

[0009] Moreover, it is a mode of this configuration 1 (2). In the solid-state-laser equipment of a configuration 1 Said solid-state-laser medium is a slab laser medium which made abbreviation long picture tabular. The configuration characterized by being what said refrigerant circulation way meets [what] crosswise [of said slab laser medium], and circulates a refrigerant, and (3) In the solid-state-laser equipment of a configuration 1 Said refrigerant circulation way considered as the configuration characterized by being what the longitudinal direction of said solid-state-laser medium is met [what], and circulates a refrigerant.

[0010]

[Function] According to the above-mentioned configuration 1, as compared with the upstream, the downstream becomes [the rate of flow of a refrigerant] large by having made the downstream small for the passage cross section of the field which cools said solid-state-laser medium in a refrigerant circulation way as compared with the upstream. Here, a cooling degree becomes high, so that the rate of flow of a refrigerant is so large that the temperature gradient of a refrigerant and a cooling medium-ed is large, when cooling the cooled body with the circulating refrigerant. In the above-mentioned configuration 1, although the temperature gradient of a refrigerant and a cooling medium-ed is large in the upstream as compared with the downstream, the rate of flow is small. In the downstream, it has this reverse relation. Therefore, if the ratio of the cross section of the upstream and the downstream is set up appropriately, the cooling degree can be made equal by the upstream and the downstream. Cooling becomes possible, without making a solid-state-laser medium produce uneven temperature distribution by this.

[0011] According to the configuration 2, a slab laser medium can be cooled without producing uneven temperature distribution also in the cross direction not to mention a longitudinal direction, and it becomes possible to cool without producing uneven temperature distribution, when a refrigerant circulation way is met and formed in the longitudinal direction of a solid-state-laser medium according

to the configuration 3.
[0012]
[Example] The important section appearance perspective view of the solid-state-laser equipment which 1st example drawing 2 requires for the 1st example of this invention, and drawing 1 are the I-I line sectional views of drawing 2 . Hereafter, the 1st example is explained in full detail, making these drawings reference. In addition, this example is an example at the time of using a YAG slab laser medium for drawing 10 as a laser medium like the solid-state-laser equipment shown as a conventional example, and there are many parts which are common to the equipment of drawing 10 . Therefore, by the following explanation, the same sign is given to a common part, a part of the explanation is omitted, and it explains focusing on a point characteristic of this example.
[0013] the passage cross section of a refrigerant circulation way 16 is the point was alike, and follows and it made become small that only the part of the difference of that thickness goes thickness to the downstream using the transparence dashboards 140a and 14b which go to the downstream and were alike, and follow and it was made become thick gradually instead of the transparence dashboards [in / in a point which is different in the conventional example this example is indicated to be to above-mentioned drawing 10 / the conventional example] 14a and 14b. Other points are the same as the above-mentioned conventional example. namely, the field where these transparence dashboards 140a and 140b counter with Lamps 12a and 12b -- the front face of the YAG slab laser medium 11, and abbreviation -- although it is an parallel field, the front face of the YAG slab laser medium 11 and the field which counters go to the downstream from the upstream -- it is an inclined plane so that it is alike, and it may follow and thickness may increase. Thereby, the passage cross section of the field which cools the YAG slab laser medium 11 in the refrigerant circulation way 16 becomes small about the downstream as compared with the upstream. The cooling water as a refrigerant flows from refrigerant inlet 160a formed in the upstream of the refrigerant circulation way 16, and is discharged through refrigerant exhaust port 160b formed in the downstream through the passage formed with the field and the transparence dashboards 140a and 140b of a front flesh side of the YAG slab laser medium 11. In this case, since the cross section of the passage formed with the field and the transparence dashboards 140a and 140b of a front flesh side of the YAG slab laser medium 11 is small as it goes to the downstream, as compared with the upstream, as for the rate of flow of cooling water, the downstream becomes large. Therefore, if the ratio of the cross section of the upstream and the downstream is set up appropriately, the cooling degree can be made equal by the upstream and the downstream, and cooling will become possible, without making a solid-state-laser medium produce uneven temperature distribution by this.
[0014] Here, in this example, Nd:YAG slab (amount of Nd dopes 1.0 atom %) with 6mm [in die length of 151mm and thickness] and a width of face of 20mm was used as a YAG slab laser medium 11. The both ends of the die-length direction of this slab took the optical path of the zigzag which makes total reflection the slant face of about 30 include angles 12 times in the interior of finishing and slab.
[0015] As lamps 12a and 12b, about 126mm of luminescence length and a krypton flash lamp (the product made from U.S. ILC, part number 10F5) with a bore [phi] of 10mm were used.
[0016] Reflectors 13a and 13b consisted of white ceramics with high reflective effectiveness (the Mitsui Mining [Co., Ltd.] make, a trade name: MASERAITO). In addition, what gold-plated the front face of the metal of aluminum and others instead of the white ceramic, and formed the reflector may be used.
[0017] The transparence dashboards 140a and 140b consisted of Pyrex glass. Although the cross section of the passage formed with the field and the transparence dashboards 140a and 140b of a front flesh side of the YAG slab laser medium 11 serves as an abbreviation rectangle here The gap of the field of a front flesh side and the front face of the transparence dashboards 140a and 140b in the edge of the YAG slab laser medium 11 of the upstream is set to 0.8mm. The gap of the field of a front flesh side and the front face of the transparence dashboards 140a and 140b in the edge of the YAG slab laser medium 11 of the downstream was set up so that it might be set to 0.3mm.
[0018] The case 15 was made into the product made from an aluminum containing alloy (a front face is alumite processing) in order to carry out maintenance closure, without leaking the YAG slab laser

medium 11, Lamps 12a and 12b, Reflectors 13a and 13b, etc.
[0019] Straightening vanes 17a and 17b consisted of Teflons (brand name of Du Pont about polytetrafluoroethylene), in order to insulate the side face of the YAG slab laser medium 11 at the same time it makes circulation of cooling water smooth.
[0020] In addition, in fact, although water cooling also of Lamps 12a and 12b and the reflectors 13a and 13b was carried out also out of the YAG slab laser medium 11, the configuration was omitted. Moreover, that configuration was also omitted, although it circulates through this pure water with a circuit system pure-water cooling system (about 40l. of about 20 refrigeration capacity kw(s) and pure-water flow rate per minute) and he is trying to circulate it, using pure water as a refrigerant which cools these. The high voltage power supply equipment for furthermore supplying drive power to Lamps 12a and 12b or its control unit is omitted.
[0021] Although the solid-state-laser equipment of an above-mentioned configuration can also be used as an optical amplifier which is made to carry out incidence of the laser beam from the end face (close and outgoing radiation side of a laser beam) of the longitudinal direction of the YAG slab laser medium 11, and amplifies this, it can constitute YAG slab laser oscillation equipment by arranging the reflecting mirror which constitutes a laser cavity on the optical path of the laser beam in the part which counters close and the outgoing radiation side of a laser beam. Then, the laser cavity was added to the solid-state-laser equipment of this example, YAG slab laser oscillation equipment was constituted, and when carrying out the multimode oscillation, as for that laser output, about 620 W was obtained in about 15kW (150J, 100pps) of electrical inputs. The laser oscillation effectiveness at this time (a laser output/electrical input) was 4.1%. Without being based on an electrical input, since the optical path length is equalized by the zigzag optical path in the thing using the conventional solid-state-laser equipment shown in drawing 10 if the post is taken in the thickness direction of slab, although it is comparatively stable, here Although there was an inclination for a longitudinal direction to become unstable, for the direction of outgoing radiation of laser to change, or for laser oscillation effectiveness to fall as the electrical input became large about the cross direction of slab In the thing of the above-mentioned example, also when changing a laser output by the electrical input, the always stable oscillation was obtained. As for fluctuation of the direction of outgoing radiation of the laser beam at this time, 0.05 or less mrads, and 1 / about five to 1/10 value of old high power solid state laser was acquired for the thickness direction of slab, and the cross direction.
[0022] In addition, in above-mentioned this example, although the slab made from a YAG crystal of amount of Nd dopes 1.0 atom % was used, of course, it is also possible to use various laser glass, such as laser crystals, such as GGG, GSGG, YSGG, YSAG, YLF, alexandrite, and sapphire, and phosphate system laser glass (5 for example, LHG[by Hoya Corp.]- 8), silic acid salt system laser glass (for example, LSG[by Hoya Corp.]- 91 H), besides a YAG crystal. Furthermore, laser activity ion is not restricted only to Nd, either and Er, Cr, Ho, Tm, and Ti may be used for others. Moreover, it is also possible to use that from which the amount of dopes of laser activity ion and a class differ if needed.
[0023] 2nd example drawing 3 is the important section sectional view of the solid-state-laser equipment concerning the 2nd example of this invention. Hereafter, the 2nd example is explained, making drawing 3 reference. In addition, since this example has many parts which are common in the 1st example, by the following explanation, it gives the same sign to a common part, omits that explanation, and explains only a point characteristic of this example.
[0024] This example makes separate passage passage 216b formed between passage 216a formed between one field of the YAG slab laser medium 11, and transparence dashboard 140a, and the field of another side of the YAG slab laser medium 11 and transparence dashboard 140b, and it is made to circulate cooling water from hard flow mutually to this passage. For this reason, the batch members 217a and 217b were attached in the both-sides side in the cross direction of the YAG slab laser medium 11 instead of the straightening vanes 17a and 17b in the 1st example, and the passage adjacent to the field of the front flesh side of the YAG slab laser medium 11 is separated. Moreover, although transparence dashboard 240a prepared in the part of which lamp 12a opposite is done is considering as the same configuration as the 1st example, transparence dashboard 240b prepared in the part of which

lamp 12b opposite is done is considering change relation of the case and thickness of the 1st example as a configuration which becomes reverse relation. And it is made to circulate in the direction shown by passage 216a by the arrow head p of drawing 3 in cooling water, and is made to make cooling water circulation carry out in the direction of p' of this and hard flow at passage 216b. It is made for the cross section of passage to become small by this as passage 216a and passage 216b go to the downstream.
[0025] Cooling which does not make a solid-state-laser medium produce uneven temperature distribution like the 1st example also according to this example is possible.
[0026] The important section sectional view of the solid-state-laser equipment which 3rd example drawing 4 requires for the 3rd example of this invention, and drawing 5 are the V-V line sectional views in drawing 4 . Hereafter, the 3rd example is explained, making these drawings reference. in addition, drawing 4 -- drawing 2 -- it is a sectional view equivalent to the IV-IV line sectional view to kick. Moreover, since there are many parts to which this example is also common in the 1st example, by the following explanation, the same sign is given to a common part, that explanation is omitted, and only a point characteristic of this example is explained.
[0027] It is the example for which it was made for this example to circulate a refrigerant along the die-length direction of a solid-state-laser medium to the 1st and 2nd above-mentioned examples having been examples which circulate a refrigerant along the cross direction of a solid-state-laser medium. And the cross section in the valley which cools the solid-state-laser medium of the refrigerant circulation way is made for the downstream to become small as compared with the upstream. Therefore, using the transparence dashboards 340a and 340b which have fixed thickness instead of the transparence dashboards 140a and 140b in the 1st example, these are installed so that it may become aslant to the longitudinal direction of the field of the front flesh side of the YAG slab laser medium 11, respectively. Passage 316a formed by this between one field of the YAG slab laser medium 11, and transparence dashboard 140a, While making into separate passage passage 316b formed between the field of another side of the YAG slab laser medium 11, and transparence dashboard 140b It is made for the cross section of passage to become small when circulating cooling water in the direction of arrow-head p of drawing to each passage as it goes to the downstream from the upstream.
[0028] According to this example, when it is made to circulate a refrigerant along the die-length direction of a solid-state-laser medium, cooling which does not make a solid-state-laser medium produce uneven temperature distribution in the die-length direction is possible.
[0029] In addition, although the rate of flow of a refrigerant covers the whole passage cross section and it was made to become about 1 appearance as are shown in drawing 5 , and the transparence dashboards 340a and 340b are used as the monotonous object which has fixed thickness and the passage cross section became an abbreviation rectangle if it was in this example For example, by using for the method of outside the transparence dashboards 341a and 341b formed in the curved-surface configuration of a convex in the cross direction instead of the transparence dashboards 340a and 340b, as shown in drawing 6 It is also possible to carry out the rate of flow of the refrigerant which passes through the center section in the cross direction of the YAG slab laser medium 11 earlier than the rate of flow in both ends. If it does in this way, when a laser medium is powerfully excited with the lamp for excitation for the purpose of high power, it will become possible to make the temperature distribution which tend to be produced based on the exposure intensity distribution of excitation light offset etc., for example.
[0030] Moreover, as shown in drawing 7 , you may make it this circulate hard flow mutually, although the circulation direction of the refrigerant which circulates two refrigerant passage 316a and 316b was carried out in this direction in the above-mentioned example. In that case, what is necessary is just to use transparence dashboard 341a which made the inclination direction reverse instead of transparence dashboard 340a.
[0031] 4th example drawing 8 is the important section sectional view of the solid-state-laser equipment concerning the 4th example of this invention. This example makes the tubing-like transparence batch tubing 44 intervene between the inner skin of this tubular YAG laser medium 41, and the lamp 42 for excitation while arranging the lamp 42 for excitation inside tubing of this tubular YAG laser medium 41, using the tubular YAG laser medium 41 as a solid-state-laser medium. When this introduces a

refrigerant into the gap formed between the peripheral face of this transparence batch tubing 44, and the inner skin of the tubular YAG laser medium 41 from one edge (left end section in drawing) of the transparence batch tubing 44, It flows into the gap in which it is formed by the inner skin of the transparence batch tubing 44, and the peripheral face of a lamp 42 as this refrigerant is turned up in the other-end section of the transparence batch tubing 44. After an appropriate time, the refrigerant circulation way 46 of the clinch method discharged from the edge of the same side as said refrigerant installation edge is formed.

[0032] In this case, it is made to become thick as the thickness of the transparence batch tubing 44 is gone to one edge (drawing Nakamigi edge), and he is trying for the cross section of the path formed by the transparence batch tubing 44 and the tubular YAG laser medium 41 an increased part of that thickness to become small. By this, it becomes large as the rate of flow of a refrigerant goes to the downstream, and it becomes possible to cool the tubular YAG laser medium 41 to homogeneity in the longitudinal direction.

[0033] In addition, in drawing 8 , a sign 43 is the reflector prepared in the periphery section of the tubular YAG laser medium 41, and a sign 45 is [refrigerant inlet and sign 45b of case and sign 45a] a refrigerant exhaust port.

[0034] 5th example drawing 9 is the important section sectional view of the solid-state-laser equipment concerning the 5th example of this invention. As this example carries out receipt arrangement of this rod-like YAG laser medium 51 into the tubing-like transparence batch tubing 54, introduces a refrigerant in the transparence batch tubing 54 from one edge (drawing Nakamigi edge) of the transparence batch tubing 54, using the rod-like YAG laser medium 51 as a solid-state-laser medium and discharges it from the other-end section, it cools the rod-like YAG laser medium 51. In this case, it is made to become thick as the thickness of the transparence batch tubing 54 is gone to one edge (left end section in drawing), and he is trying for the cross section of the refrigerant circulation way 56 formed by the transparence batch tubing 54 and the rod-like YAG laser medium 51 an increased part of that thickness to become small. By this, it becomes large as the rate of flow of a refrigerant goes to the downstream, and it becomes possible to cool the rod-like YAG laser medium 51 to homogeneity in the longitudinal direction.

[0035] In addition, while the rod-like YAG laser medium 51 and the transparence batch tubing 54 are contained inside the case 55, this rod-like YAG laser medium 51 is excited with the lamp 52 for excitation which is the interior of a case 55 and has been arranged on the outside of the transparence batch tubing 54. Moreover, while the reflector 53 is formed in the inner skin of the case 55 in the circumference of the lamp 52 for excitation, the other-end section is combined with refrigerant inlet 55a by which one edge of the transparence batch tubing 54 was established in the case 55 by refrigerant exhaust port 55b, respectively.

[0036]

[Effect of the Invention] When this invention made the downstream small for the passage cross section of the field which cools the solid-state-laser medium in the refrigerant circulation way which cools a solid-state-laser medium as compared with the upstream, it is made for phase murder and the uneven temperature distribution based on cooling not to produce the difference of the cooling degree based on the temperature gradient of the refrigerant in the upstream and the downstream to a solid-state-laser medium by this, as are explained in full detail above, and the downstream becomes large from the upstream about the rate of flow of a refrigerant.

[Translation done.]